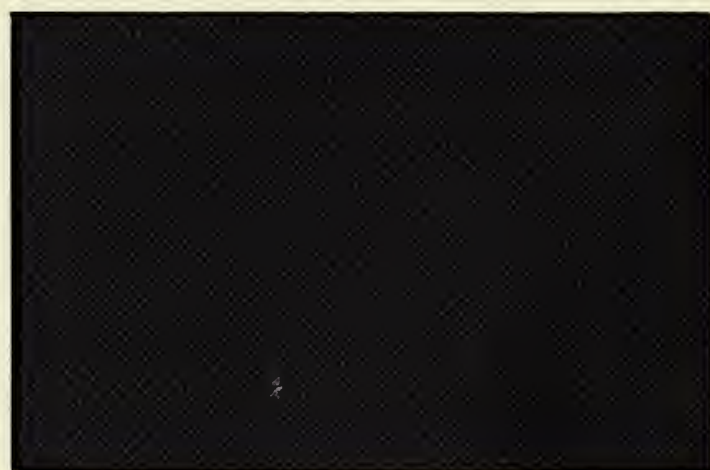


BROWN AND CAJON WELLS

**Biscayne Bay Shoreline Model
Technical Memorandum**

**Old South Dade Landfill
Closure Enhancement
Miami-Dade County, Florida**

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Biscayne Bay Shoreline Model Technical Memorandum

**Old South Dade Landfill
Closure Enhancement
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Biscayne Bay Shoreline Model Technical Memorandum

**Old South Dade Landfill
Closure Enhancement
Miami-Dade County, Florida**

Submitted to:

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Miami, Florida 33166**

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December 1999

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1.0 Introduction

Proposed remedial activities of the shallow Biscayne aquifer at the Old South Dade Landfill (OSDL) include extraction of ammonia-impacted groundwater, treatment, and re-injection of the treated water. Extraction of groundwater will occur from the shallow, G-II (freshwater) aquifer and re-injection of treated groundwater with ammonia concentrations below 0.5 mg/l will occur in the deeper, G-III (saltwater) aquifer. Based on the review of the Remedial Action Plan dated July, 1998, the National Park Service (NPS) has expressed concerns regarding the potential for low concentration ammonia discharge to Biscayne Bay associated with migration of re-injected treated groundwater. In their letter dated January 25, 1999, the NPS requested: 1) installation of additional groundwater monitoring wells in the Bay very near to shore, and 2) additional numerical modeling to further assess the hydrogeological interactions of the proposed remedial system near the Bay.

Brown and Caldwell proposed to address the NPS concerns with additional Site characterization and groundwater flow modeling to support the siting of a near-shore monitoring location. Establishing a monitoring location to collect data regarding current discharge concentrations to the Bay will provide a basis for assessing potential discharge due to injection of treated water.

This technical memorandum summarizes the results of additional Site characterization and groundwater flow modeling. The revised conceptual model, results of modeling activities, and recommendations for siting a near-shore monitoring location are presented.

A consensus meeting to discuss well siting, well installation and sampling protocol will be held prior to initiating a water quality sampling event.

2.0 Conceptual Model

The existing groundwater model (Remedial Action Plan, 1998) incorporated regional flow directions and gradients, canals, recharge, evapotranspiration, and groundwater withdrawals from the operating landfill to the north of the OSDL Site (Figure 1). To expand the conceptual model, two additional components were added to the conceptualization: discharge of groundwater to Biscayne Bay, the saltwater/freshwater interface, and the density-dependent flow regimes of the near-shore zone.

Discharge to Biscayne Bay. The issue of coastal freshwater discharge to Biscayne Bay is currently the subject of extensive research. Freshwater discharge reductions to the Bay caused by the lowering of the water table via managed canal and control structures has modified the groundwater flow patterns in southern Florida. Quantification of groundwater discharge to Biscayne Bay, not directly measurable in the field, is part of an on-going groundwater modeling project by the United States Geological Survey (USGS) as part of the South Florida Ecosystem Program.

Based on the current understanding, freshwater discharge to the Bay was observed and documented prior to 1960. Freshwater discharge was estimated to extend approximately 300 feet offshore, based on an analysis of freshwater equipotential (Kohout, 1964). Since that study, the general lowering of the water table has reduced the pressure gradient, the major mechanism for freshwater discharge to the Bay. Preliminary data from the USGS research on discharge into the Bay support the concept of near-shore discharge; data suggest that most discharge is limited to within 150 feet of the shoreline (Langevin, 1999).

Saltwater Interface. A result of decreased freshwater discharge is the intrusion of saltwater into the Biscayne aquifer system. A wedge of saltwater exists in the aquifer system underlying the freshwater in the coastal region, and extends for miles inland. Data from 1995 analyzed by Sosenshein (1996) indicates that the toe of the saltwater zone is approximately two miles west of the Old South Dade Landfill Site.

The contact between freshwater and saltwater, termed the saltwater interface, is defined as the 10,000 mg/L Total Dissolved Solids (TDS) contour line. Although defined as a sharp contact, the interface is actually a large diffuse zone of varying concentrations (Sosenshein, 1996), formed by the mixing of freshwater with denser saltwater (Figure 2). The mixed water zone is called the zone of diffusion. Hydrogeologic parameters of the aquifer system, such as gradient, hydraulic conductivity and water level fluctuations, will impact the thickness of this zone. Additionally, if the aquifer is subject to water level variations caused by tides, the zone of mixed water will be enlarged (Fetter, 1994). The resulting groundwater system is comprised of two separate miscible fluids: freshwater and saltwater. The density differences between the water types exerts control on the flow regime, discussed in the following section.

Density-Dependent Flow Regimes. In the near-shore aquifer system at Biscayne Bay, salinities vary over short distances both laterally and vertically. Density differences caused by the varying salinities separate the aquifer system into three separate, interconnected flow regimes. Figure 3 is the location of the freshwater/saltwater interface based on the most recent water quality analyses from the on-site monitoring well network (OS1 through OS5) and from salinity profiles completed in the injection pilot test well (IW-5). Based on the salinity profiles, the zone of diffusion was a minimum of 40 feet thick (Figure 4). The curve of the freshwater/saltwater interface was extrapolated to the shoreline, to aid in the development of a conceptual model of the saltwater interface and the zone of diffusion in the vicinity of the OSDI Site and Biscayne Bay.

Figure 5 is a west/east cross section of the flow patterns in the freshwater, diffusion and saltwater zones. This conceptualization combines on-Site geologic and hydrogeologic data, research on the relationship between freshwater and saltwater flow and coastal discharge in the Miami area (Robinson and Gallagher, 1999; Cooper, 1964; Kohout, 1964), and preliminary data from the on-going USGS modeling study of groundwater discharge to Biscayne Bay.

Separate flow regimes are depicted for freshwater and saltwater, which are separated by the zone of diffusion. The edges, or boundaries, of the zone of diffusion are restrictions to flow. The upper boundary acts as a barrier to flow of pure saltwater, the lower boundary acts as a barrier to flow of pure freshwater.

Saltwater moves inland beneath the freshwater lens in a circulatory pattern. Inland flow of saltwater is largely in the deeper portions of the aquifer (Cooper, 1964), although mixing at the interface causes a component of horizontal flow along the length of the interface.

Groundwater in the freshwater portion of the aquifer moves seaward, and encounters saline water at the saltwater/freshwater interface. Mixing occurs at the interface, which is enhanced by tidal fluctuations. Both the freshwater and mixed waters are less dense than pure saltwater, and move up along pathlines indicated on Figure 5. Due to the density gradients, continuous mixing occurs in the diffuse zone as water moves upward along the interface. Toward the upper portion of the aquifer,

waters in the zone of diffusion are representative of combined freshwater and saltwater from all layers in the aquifer.

Discharge into the Bay consists of freshwater from the shallow aquifer system and mixed water from the zone of diffusion (see enlargement, Figure 5). Most groundwater discharge was estimated to occur within 150 feet of shoreline. Based on research in the vicinity (Langevin, 1999), a freshwater component extends offshore approximately 900 feet. This represents a limit for the lateral extent of discharge, and it is assumed that discharge with any freshwater component at all occurs within this near-shore zone.

Impacts of Injection. As proposed in the RAP, treated groundwater from the shallow, G-II aquifer (freshwater) will be re-injected into the deeper, G-III aquifer (saltwater) for disposal. The injection interval is from -60 to -100 ft below sea level (bsl). The injection wells are located approximately 4,500 feet from the shoreline (see injection well IW-5 on Figure 6). The injection interval at this location is within the diffusion and saltwater zones. Freshwater injected into these zones will produce a freshwater mound that mixes and moves up until reaching a density equilibrium. As the freshwater moves up, the density gradient becomes smaller, reducing the mechanism for vertical movement. As the driving mechanism is diminished, horizontal gradients will begin to influence flow, and a horizontal component of flow will cause injectate to move up and east toward the Bay. Injectate will likely reach a density equilibrium near the upper boundary of the zone of diffusion, just below the freshwater zone (Figure 6). Continuous mixing with saltwater and freshwater will occur as the injectate moves along the boundary. The semi-confining layer is a barrier to upward migration of water into the shallow zone, as indicated by the small vertical arrows in that region.

3.0 Numerical Groundwater Model

The expanded conceptual model incorporates some complexities that were not contained in the active modeled area of the existing groundwater flow model for the Site. These include the freshwater/saltwater interface, separate flow regimes for freshwater and saltwater, freshwater discharge to the Bay, and groundwater flow in the aquifer underlying the Bay. A review of modeling studies of analogous systems was conducted to assess the different simulation methods and their relative successes. To best simulate the density-dependent interactions between the freshwater and saltwater systems, and to achieve the resolution required to depict shoreline discharge, finite element models utilizing pressure head and salinity in the governing equations for groundwater flow and contaminant transport were most prevalent.

MODFLOW (McDonald and Harbaugh, 1988), a three-dimensional, finite difference groundwater model that calculates groundwater heads and budgets, was used to develop the existing model. MODFLOW is not density-dependent, and its finite difference structure is less applicable to non-linear boundary conditions. This precluded direct modeling of the dual-density system with the existing model. Model development therefore focused on the freshwater flow regime.

The active area of the existing numerical groundwater model was expanded to include the shoreline and near-shore regions in Biscayne Bay. The existing finite difference grid ranged from 60-foot squares on site to 200-foot squares toward the edges of the modeled area. The refined area of smaller 60-foot grid cells was expanded to include the shoreline and near-shore regions. Sources of

water into the expanded groundwater system include leakage from canals, infiltration of precipitation, and underflow. Water leaves the groundwater system via discharge into Biscayne Bay, leakage into canals, evapotranspiration, and underflow.

The observed hydrogeologic components of the remedial system and the aquifer system are discussed below, followed by the approach taken to simulate each component in the numerical model.

The Remedial System. The remedial system at the OSDL will consist of extraction wells, water treatment, and injection wells to dispose of treated groundwater. Five extraction wells pumping at rates that vary from 101 to 156 gallons per minute (gpm) will hydraulically control the shallow groundwater system, capturing ammonia impacted groundwater underlying Area III of the OSDL (Figure 7). Total daily treatment volumes will be approximately 925,000 gallons. Once treated, groundwater will be re-injected into the deeper (G-III) aquifer of the Fort Thompson Formation, below the 10,000 TDS concentration contour delineating the boundary between freshwater and saltwater. A total of five injection wells each injecting 127 gpm to dispose of the treated groundwater will be located approximately 300 feet east (downgradient) of the pumping wells (Figure 7). The injection wells will be surrounded by percolation ponds which dispose of stormwater collected as runoff from Area III. During large-scale storm events, runoff will drain into the injection wells.

Injection of treated, fresh groundwater below the 10,000 TDS concentration contour will change the vertical gradients in the vicinity of the injection wells. An upward vertical gradient currently exists, which will be enhanced by 1) the positive pressure response in the deeper system due to injection, and 2) the introduction of freshwater into the saline environment, creating density differences that increase upward movement. Mounding due to injection was simulated (Remedial Action Plan, 1998), was approximately 0.17 feet (0.17 feet), and was restricted to the immediate vicinity of the well. Upwelling due to density differences cannot be directly simulated with the MODFLOW model.

Pumping and extraction were simulated with wells in the groundwater model. Percolation ponds were simulated using a real recharge rates set at the design percolation rate. By varying the well injection rates and the duration of percolation, both daily operating conditions, small scale storm events, and a 100-year storm event were simulated.

Biscayne Aquifer. The thickness of the Biscayne aquifer in the vicinity of the OSDL is approximately 100 feet, based on subsurface investigations conducted on-Site (Brown and Caldwell, 1999). The Biscayne aquifer in the vicinity of the site is comprised of the Miami Limestone and the Fort Thompson Formation, which are separated by a semi-confining layer that occurs at the contact, approximately 25 feet below sea level (ft bsl). The semi-confining layer does not eliminate vertical flow, but acts as a barrier to vertical groundwater movement.

Separate layers within the numerical model were used to represent the Miami Limestone, the Fort Thompson Formation and the semi-confining layer at the contact. Hydrogeologic parameters were estimated based on pumping tests in the shallow Miami Limestone and injections tests in the deep Fort Thompson Formation, designed to assess the hydraulic connection between aquifers. Relatively high values of hydraulic conductivity were utilized for the Miami Limestone and Fort Thompson Formation (3,000 to 3,500 ft/day); relatively low values of hydraulic conductivity were used for the semi-confining layer (50 ft/day). Vertical leakage in the semi-confining layer was set

two orders of magnitude lower than in the Miami Limestone and Fort Thompson Formation. Due to the large disparity in conductivities, preferential flowpaths are primarily horizontal and limit hydraulic communication between aquifer units.

Flow Regime. Groundwater flow across the OSDL is to the east/southeast. The flow regime in the vicinity of the Site is governed by two major hydrogeologic controls: diurnal tides and canals. The Goulds canal runs west/east along the northern boundary of the entire Site, a spillover gate drains water from the canal into the Bay. The L31E canal connects to the Goulds Canal and runs north/south, between Areas II and III (Figure 1). The L31E is an uncontrolled flood management structure. The canals are excavated into saturated Miami Limestone and are assumed to have direct hydraulic connection to the aquifer. Two large west/east canals with control structures are located to the north (Black Creek canal) and south (Princeton canal) of the Site. Canal levels are generally lower in the summer in anticipation of large influxes of water, and higher in the winter.

Canals were simulated with the River Package of MODFLOW, an internal boundary that allows water to move into, or out of, the groundwater system, depending upon the gradient between the river stage and the aquifer.

Two distinct seasons are recognized in this coastal climate: the dry season representing low-water months during the winter and spring, and the wet season representing summer and fall. Seventy-five percent of the total estimated rainfall of 55 inches per year falls during the summer months (Merritt, 1996). In addition to seasonal water level variations, the aquifer system in the vicinity of the site is subject to tidal fluctuations. Monitoring of water level elevations during a 12-hour tidal cycle showed that tidal variations were dampened by canal impacts. Areas I and II (Figure 7) showed a tidal response of approximately 0.5 ft and Areas III and IV, west of the L31E canal showed a tidal response of approximately 0.1 ft. Flow direction and gradient were maintained throughout the diurnal perturbations.

The numerical model was designed to simulate the nominal system, midway between the high and low water season. Tidal variations were not directly simulated, water levels reflected average tidal conditions.

Saltwater Interface. The lower boundary of the zone of diffusion was conceptualized as a barrier to freshwater flow (Figure 5) that forms a sharp interface between the freshwater and saltwater regimes. Although the zone of diffusion is known to be a transient feature, not well represented by a sharp boundary, the simplifying assumption of a sharp boundary was made for simulation purposes. This representation of a sharp boundary is conservative because the discharge is restricted to flow along the interface and not dispersed in a mixing zone throughout the interface.

The boundary separating freshwater from saltwater was simulated with horizontal flow barriers in MODFLOW. Horizontal flow barriers are located between cells and use a barrier transmissivity to lower the horizontal branch conductance between the two cells that they separate. Barriers to flow were positioned vertically along the saltwater front, and staggered between layers to approximate the curving boundary condition.

Sources/Sinks. Water enters the active modeled area as underflow from upgradient sources, canal leakage, and infiltration from precipitation. Water leaves the active modeled area as underflow, discharge into the Bay, leakage into the canals, and evapotranspiration.

Underflow in and out of the active model area was simulated with constant head boundaries to the west and east. The western constant head boundary was set at 2 feet, and the eastern boundary, moved approximately one mile offshore during model expansion, was set at sea level. Canal leakage, discussed previously, was simulated with River cells. Impacts of precipitation and evapotranspiration were simulated with the Recharge and Evapotranspiration Packages of MODFLOW, respectively. Groundwater discharged into the Bay leaves the groundwater system, and moves into the surface water system. Conceptually, this discharge exits the groundwater model domain. Shoreline discharge was simulated with the Drain Package. Drains are interior model boundaries that remove water from the modeled area when water levels are higher than a user-defined stage in the drain cell. Preliminary results from the USGS shoreline discharge model were not yet available for calibration to actual flux rates; rough estimates of discharge were calculated within the model, based on a drain stage of 0.5ft msl. Figure 8 shows all boundary conditions used for the expanded groundwater model.

4.0 Results

Use of the horizontal flow boundary successfully simulated the vertical components of freshwater flow depicted in the conceptual model. Model results incorporated a component of discharge into the Bay designed to remove water from the groundwater system near the shoreline. Freshwater discharge to the Bay ranged from 60 to 80 ft³/day per foot of shoreline. Due to insufficient data regarding the observed geometry of the saltwater interface at the shoreline, the simulated discharge was not calibrated to field conditions. Although discharge was an uncalibrated component of the aquifer system, based on background research and our understanding of the aquifer system, discharge rates in this range are plausible.

Particle tracking simulations to calculate flow-paths of groundwater were run with the expanded model. Particle tracking simulations are based on the cell-by-cell fluxes and directions of flow that are calculated in the MODFLOW groundwater flow model. These outputs are used by MODPATH (Pollock, 1994) to calculate velocity and direction of flow of a particle “released” into the flow system. The MODPATH module was used to track groundwater injected between 60 and 100 feet below sea level (ft bsl). Figure 9 shows the flow-paths of water particles released in the injection interval. The arrows on the flow-path lines are one-year intervals. Released particles reached the shoreline after approximately 4 to 6 years. Note that the estimated time to move up through the aquifer system and reach the shoreline is based on the nominal flow system, midway between high and low tides. Tidal impacts and major fluctuations in water levels associated with seasonal recharge are not reflected in this estimate. Further, because the interface is represented as a sharp interface, the simulated flow-paths are likely conservative and represent the lower bound of time to discharge into the Bay.

5.0 Recommendations

Well Site. Additional background investigations were conducted to identify related studies and existing near-shore monitoring locations to maximize the benefits from the proposed new well. Ongoing investigations related to groundwater or surface water are being conducted by the United States Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA),

the National Park Service (NPS), the Army Corps of Engineers (COE), and Florida International University (FIU). Contacts were made with these agencies to locate existing offshore monitoring wells in the vicinity of the Site.

The USGS well cluster adjacent to Black Point (BP1A and BP1B) is closest to the OSDL Site. The wells are located approximately 2,000 feet offshore, too far to be useful in the assessment of potential concentrations of ammonia in near-shore Bay discharge, but located at what could be the endpoint of a groundwater monitoring transect of wells across the Site and into the Bay, once the near-shore monitoring well is installed.

Based on the conceptual and numerical groundwater models, the optimal location for the proposed new near-shore monitoring well is adjacent to the OSDL Site, within 50 feet of the shoreline, as shown on Figure 10. This location is:

- midway between the Goulds Canal to the north and the Princeton canal to the south, reducing potential influences of canal discharge on water quality sampling events;
- inland of the USGS Black Point monitoring wells in the Bay, forming a transect of monitoring wells across the Site and out into the Bay; and
- immediately downgradient of the landfill and within the groundwater discharge zone, thus representative of the concentrations of ammonia that will discharge into the Bay.

However, the well location is within the mangrove fringe present along the shoreline of the Bay. The mangrove system has been identified as a natural producer of ammonia (NPS, 1999), and the water quality results from this location may be impacted. It is requested that the NPS aid in the quantification of the potential contribution of the mangrove fringe to the water quality results to better assess nitrogen speciation in the system.

Sampling Protocol. To coincide with existing on-Site monitoring and take advantage of available data from the nearby monitoring wells, the new proposed well should be a multi-port well, or a well cluster, to provide a vertical profile of nitrogen species. Suggested sampling intervals are: surface water, 1-6 ft below the rock surface (to be consistent with the existing off-shore wells); 15-20 ft below the rock surface (to be consistent with the existing off-shore wells); and 40 to 50 ft below the rock surface, to assess concentrations in the deeper G-III aquifer.

A sampling event to include all on-Site and off-shore monitoring wells is recommended, to provide a “snap shot” of concentrations, assess the dominant geochemical processes at work in the aquifer systems and improve our understanding of the subsurface nitrogen speciation downgradient of the landfill. To accomplish this, samples must be analyzed for the full suite of nitrogen species. To more closely tie in with existing monitoring projects, it is recommended that split samples be collected and analyzed by the respective labs for Miami-Dade Solid Waste, the USGS, and FIU. These three entities have existing databases of water quality analyses and slightly different methodologies for sample collection and preservation. Split samples will remove some of the ambiguities inherent in comparing results using differing methodologies. A consensus meeting to discuss the well installation and define a sampling plan will be held subsequent to the submittal of this memorandum.

6.0 Summary

- Conceptually, the aquifer system near the Bay is density dependent. Simplifying assumptions were made to simulate key components of the freshwater system.
- Expanded conceptual and numerical models of the OSDL Site were utilized to assess the hydrogeologic components of the shoreline environment. Revisions to the groundwater model were successful in simulating the vertical components of freshwater flow and shoreline discharge depicted in the conceptual model. Uncalibrated shoreline discharge ranged from 60 to 80 ft³/day per foot of shoreline. Particle tracking was performed to determine the optimal location for the proposed new monitoring well.
- Recommendations on the well design and sampling protocol were made, and were intended to take advantage of existing databases, minimize ambiguities in results, and provide an overview of nitrogen speciation along a transect from the OSDL Site to the Bay. The recommended well site is within 50 feet of the shoreline.
- The NPS is requested to aid in the quantification of the natural production of ammonia by the mangrove fringe, in order to more accurately assess the nitrogen speciation across the proposed monitoring transect.

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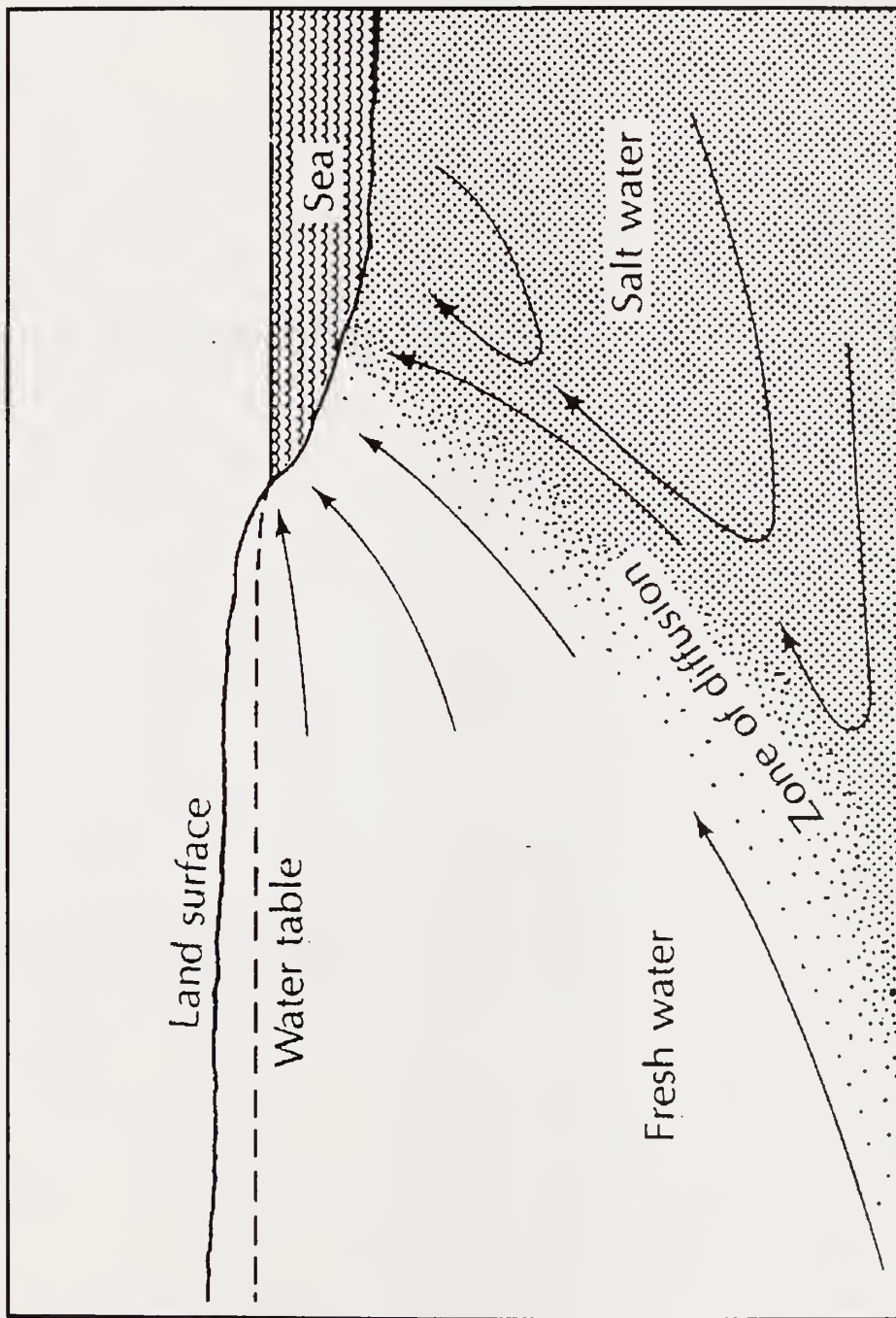
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Figure 1
 OLD SOUTH DADE LANDFILL CLOSURE ENHANCEMENT
**TOPOGRAPHIC BASEMAP OF THE OLD SOUTH DADE
 LANDFILL SITE**
 DADE COUNTY, FLORIDA

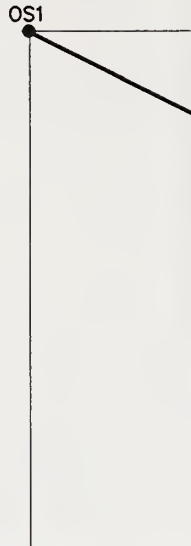


Source: Cooper, 1964

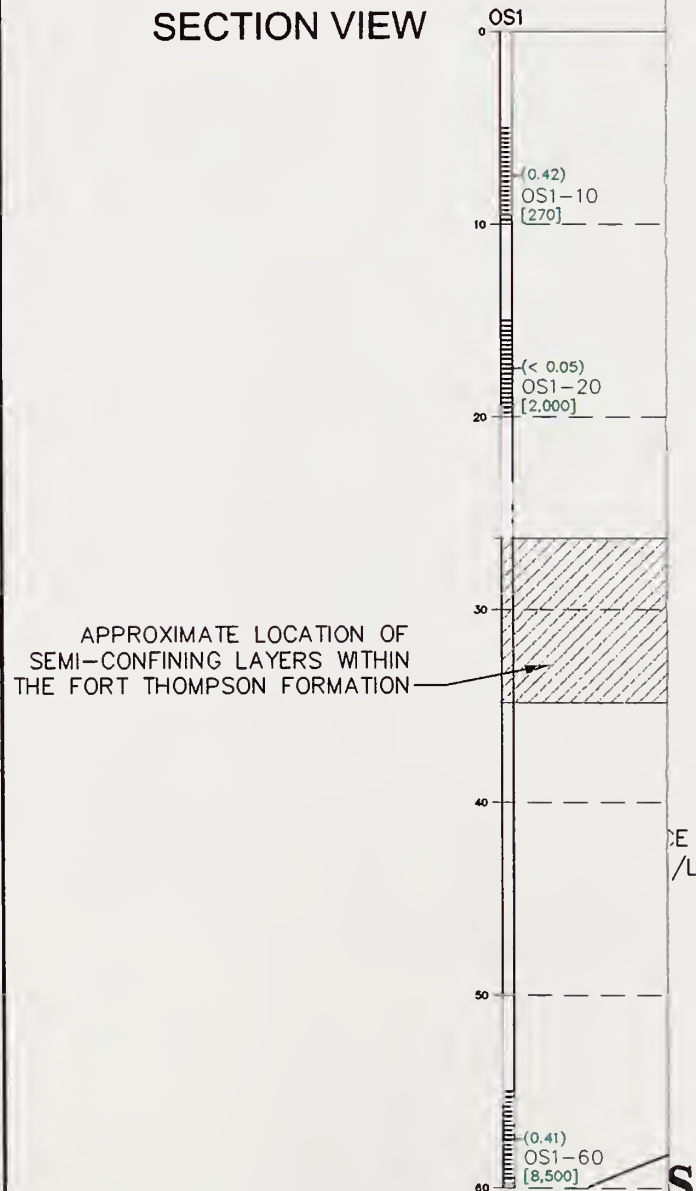
Figure 2
 OLD SOUTH DADE LANDFILL CLOSURE ENHANCEMENT
 FRESHWATER/SALTWATER INTERFACE AND THE
 ZONE OF DIFFUSION
 DADE COUNTY, FLORIDA

BROWN AND CALDWELL

PLAN VIEW



SECTION VIEW



0 500 1000

APPROXIMATE
SCALE IN FEET

EXPLANATION



SURFACE WATER



WELL SCREEN

(1.63)

TOTAL AMMONIA
CONCENTRATION (mg/L)

[460]

TOTAL DISSOLVED SOLIDS (TDS)
CONCENTRATION (mg/L)



MONITORING WELL CLUSTER



OLD SOUTH DADE LANDFILL
PROPERTY BOUNDARY



SECTION CUT LINE



TOTAL AMMONIA ISO-CONCENTRATION
CONTOURS (mg/L)

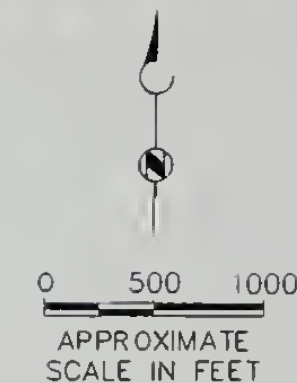
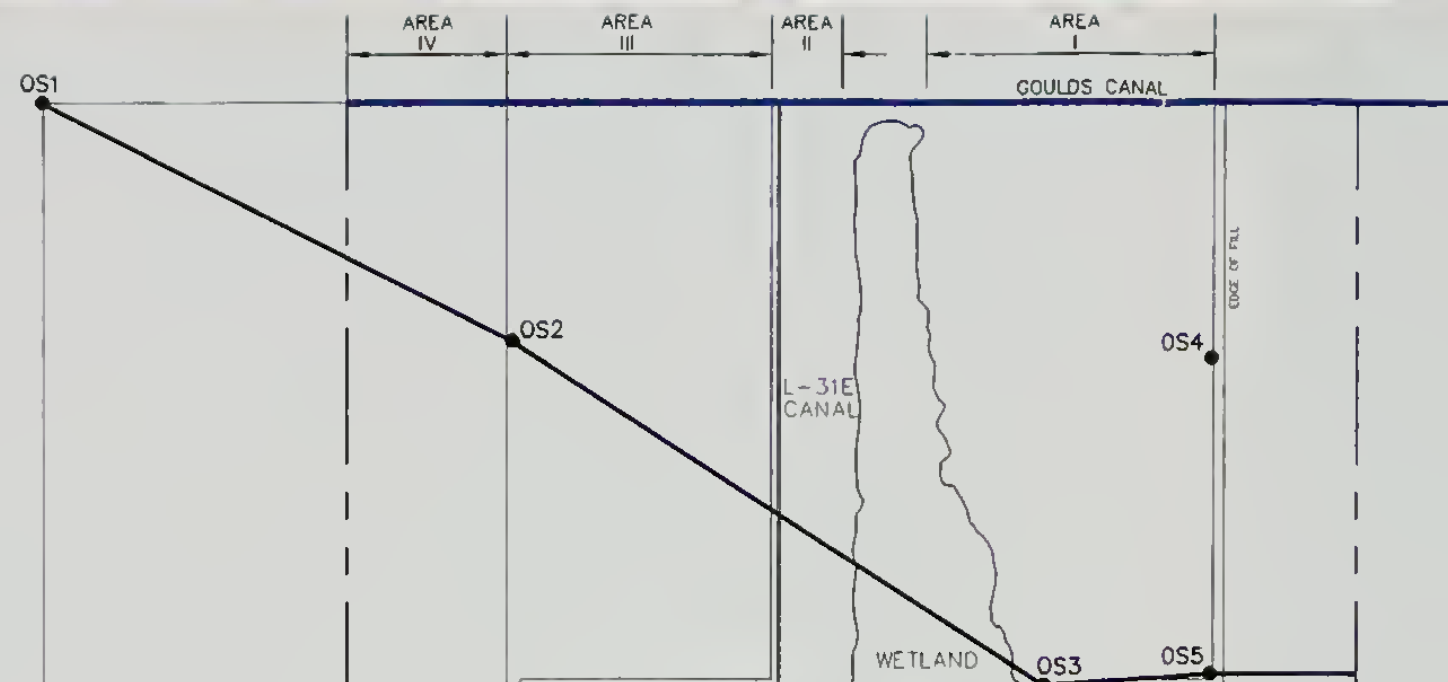
NOTE: AMMONIA AND TDS
CONCENTRATIONS FROM SUMMER,
1999 DSWM SAMPLING EVENT.

Figure 3

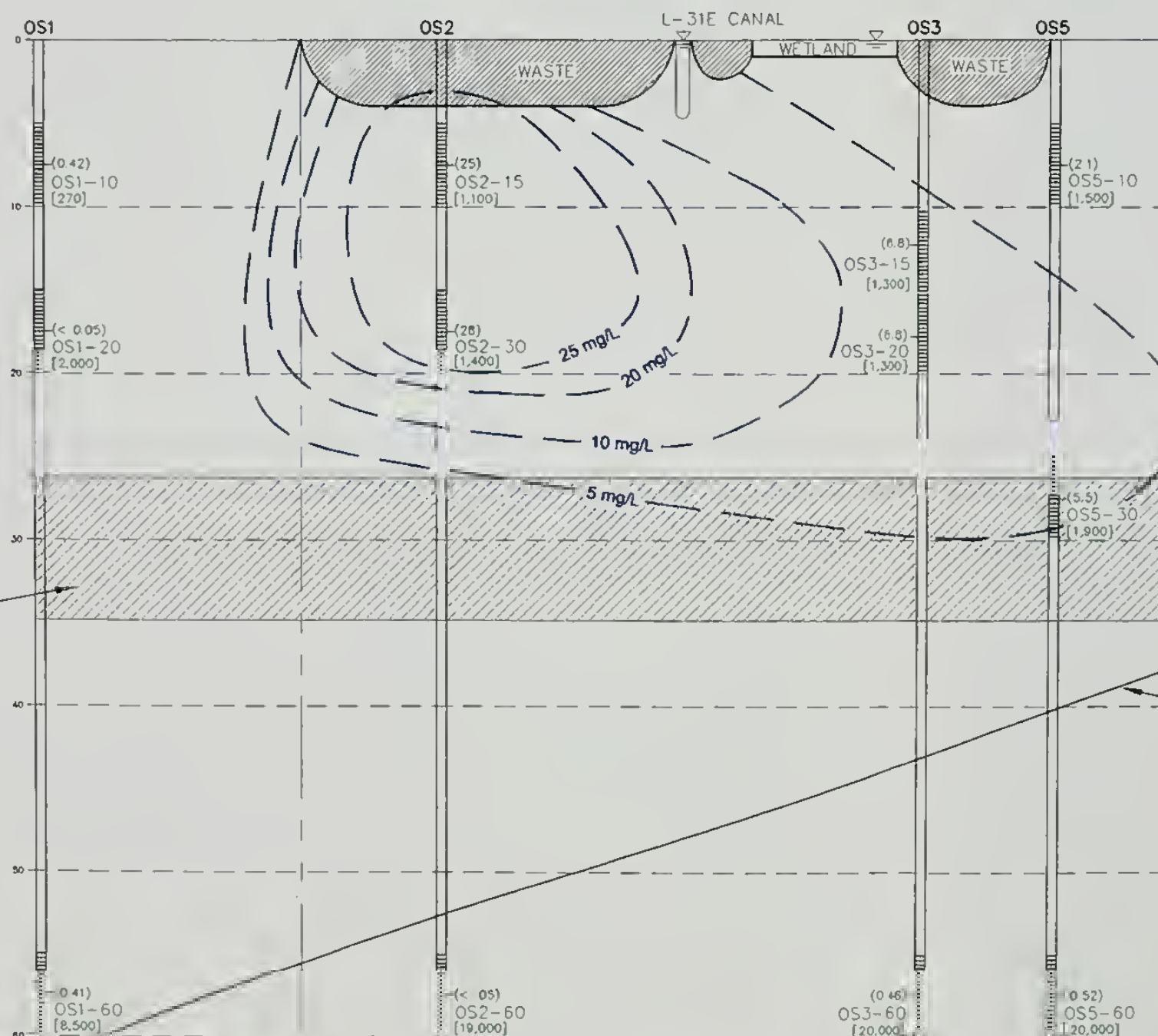
**LOCATION OF THE
SALTWATER/FRESHWATER
INTERFACE - SUMMER 1999
OLD SOUTH DADE LANDFILL
CLOSURE ENHANCEMENT**

BROWN AND CALDWELL
Phoenix, Arizona

PLAN VIEW



SECTION VIEW



EXPLANATION

- SURFACE WATER
- WELL SCREEN
- TOTAL AMMONIA CONCENTRATION (mg/L)
- TOTAL DISSOLVED SOLIDS (TDS) CONCENTRATION (mg/L)
- MONITORING WELL CLUSTER
- OLD SOUTH DADE LANDFILL PROPERTY BOUNDARY
- SECTION CUT LINE
- TOTAL AMMONIA ISO-CONCENTRATION CONTOURS (mg/L)

NOTE: AMMONIA AND TDS CONCENTRATIONS FROM SUMMER, 1999 DSWM SAMPLING EVENT.

APPROXIMATE LOCATION OF SEMI-CONFINING LAYERS WITHIN THE FORT THOMPSON FORMATION

APPROXIMATE LOCATION OF SALTWATER/FRESHWATER INTERFACE TDS CONCENTRATION ≥ 10,000 mg/L

BROWN AND CALDWELL
Phoenix, Arizona

Figure 3
LOCATION OF THE
SALTWATER/FRESHWATER
INTERFACE - SUMMER 1999
OLD SOUTH DADE LANDFILL
CLOSURE ENHANCEMENT

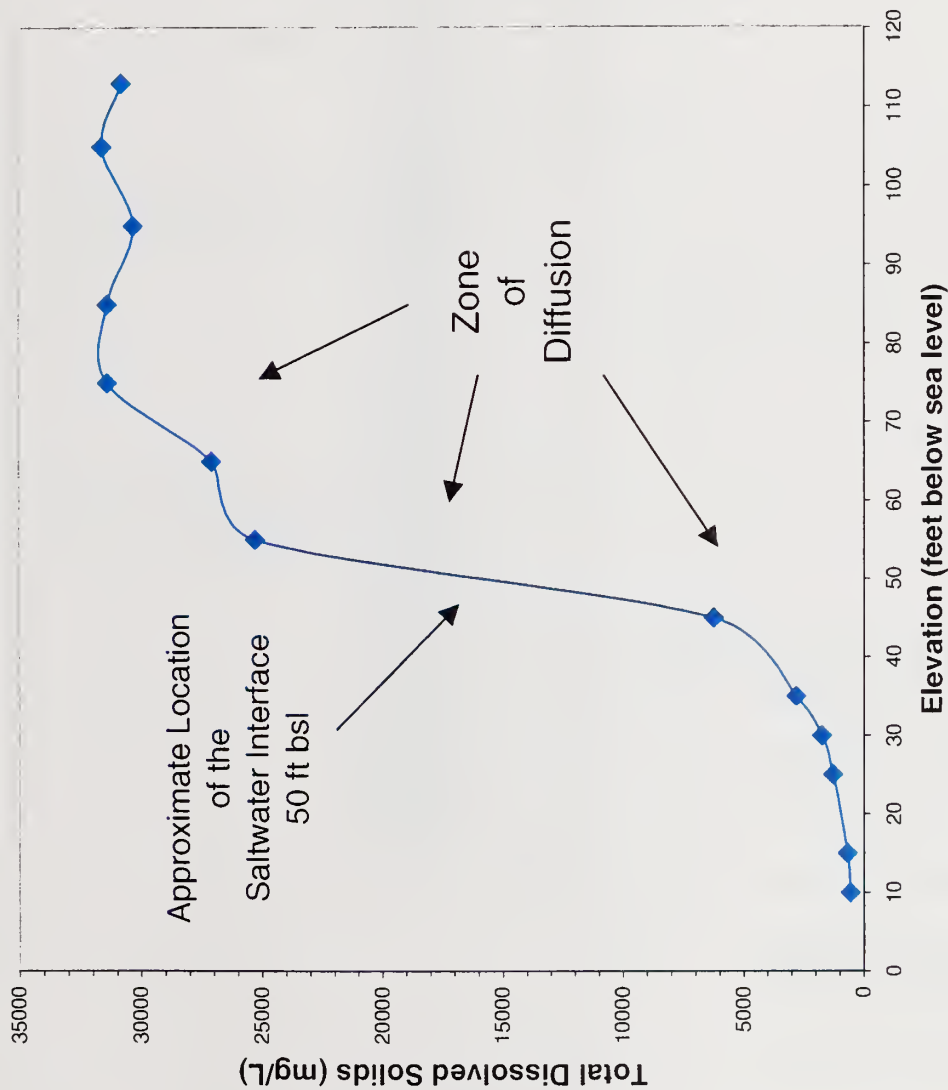
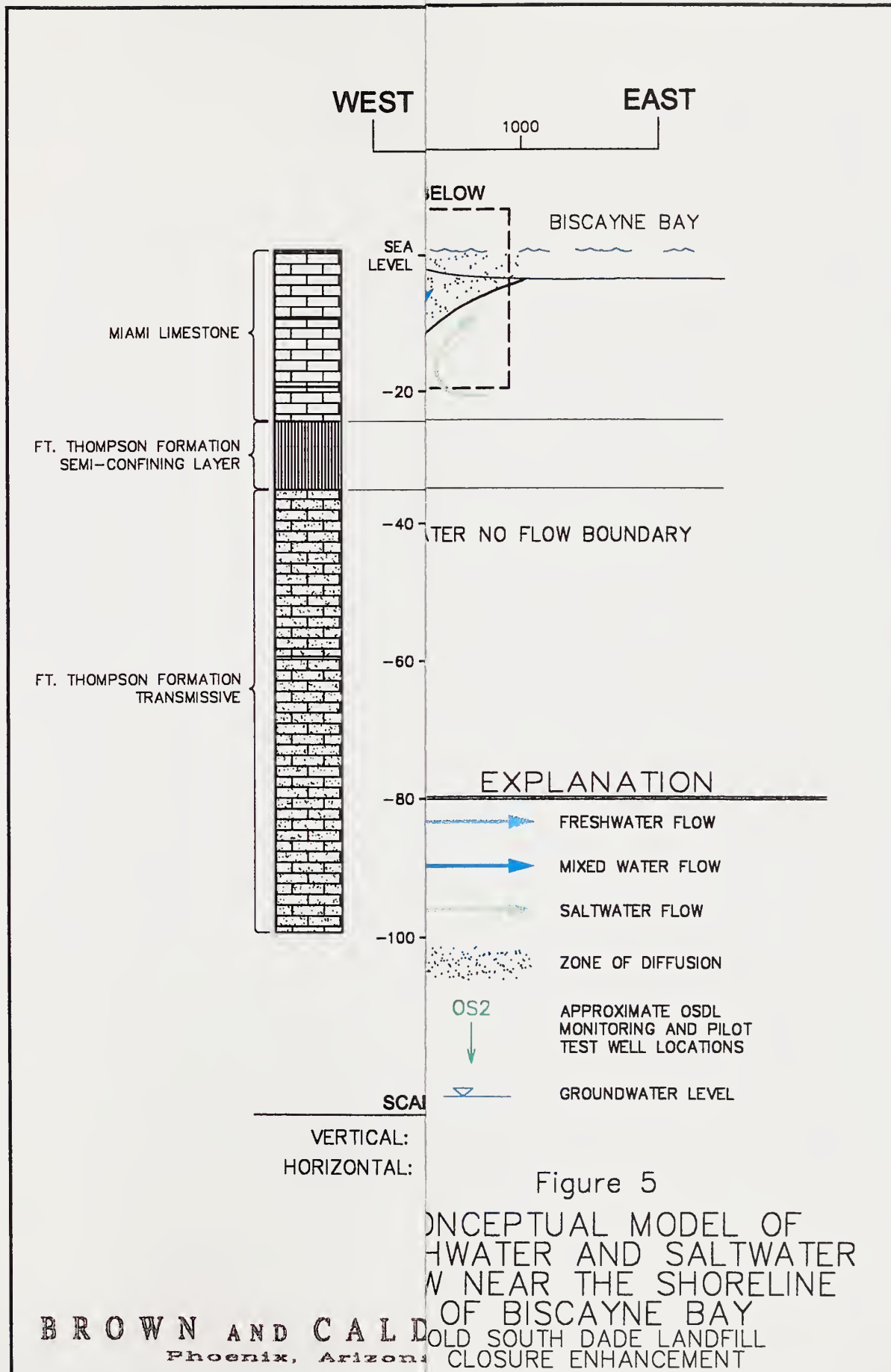
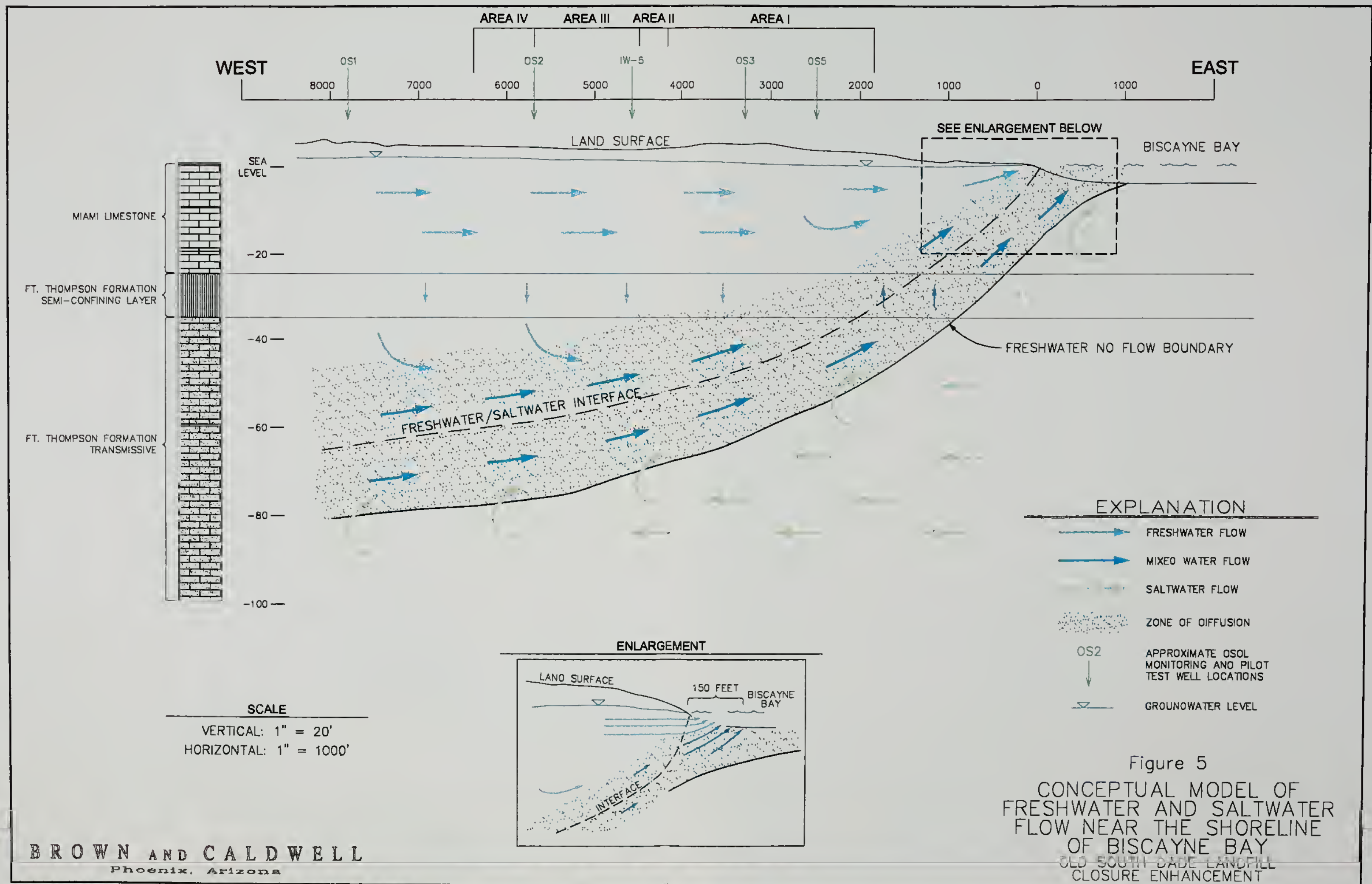
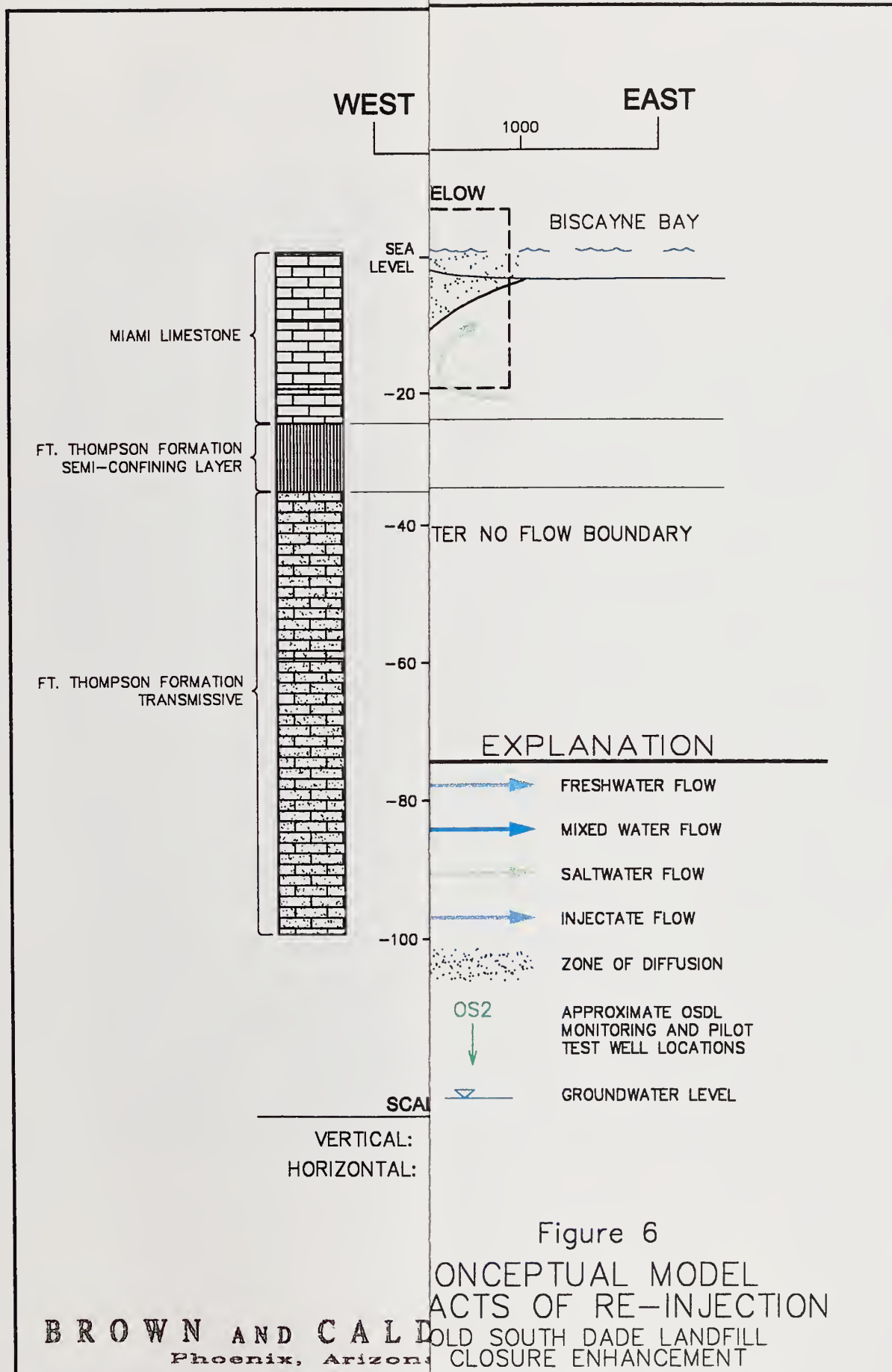


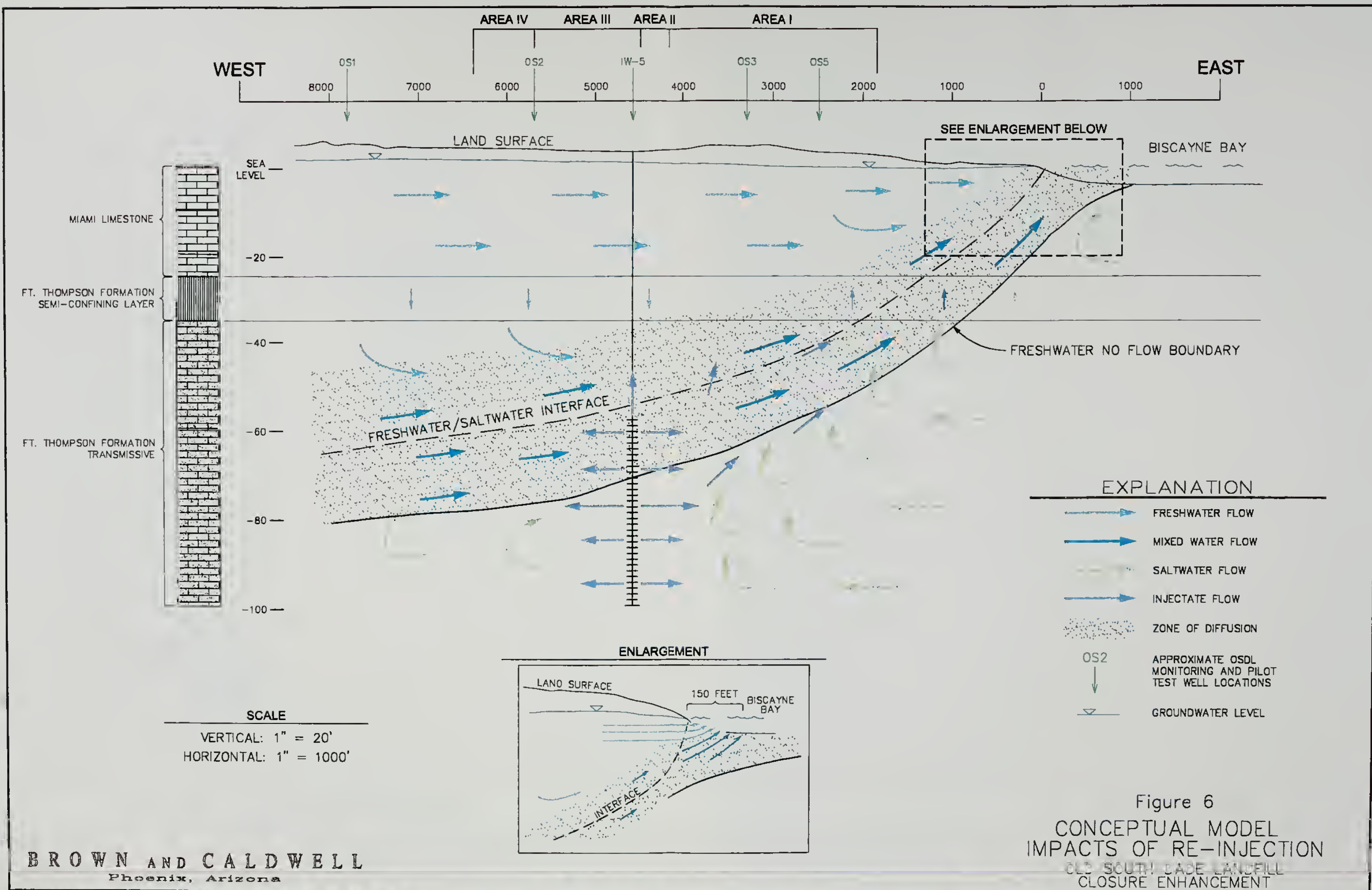
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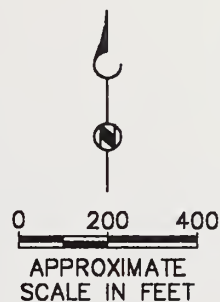
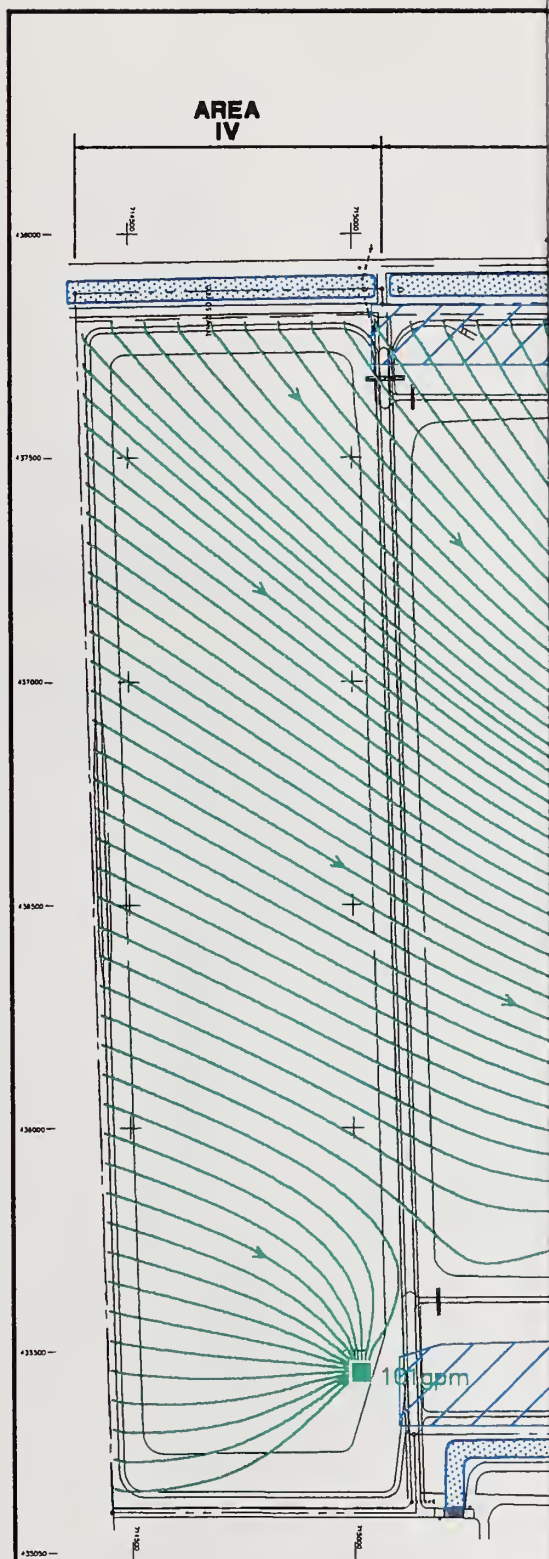
OLD SOUTH DADE LANDFILL CLOSURE ENHANCEMENT
 SALINITY PROFILE IN THE INJECTION PILOT TEST
 COREHOLE - MAY, 1999
 DADE COUNTY, FLORIDA











EXPLANATION

- 156gpm PUMPING WELLS WITH EXTRACTION RATE (gallons/minute)
 - 107gpm INJECTION WELLS WITH EXTRACTION RATE (gallons/minute)
 - ▨ STORMWATER RETENTION POND
- TOTAL PUMPING
924,480gpd (gallons/day)

Figure 7

OLD SOUTH DADE LANDFILL
CLOSURE ENHANCEMENT
HYDRAULIC CONTAINMENT
EXTRACTION/INJECTION SYSTEM
DADE COUNTY, FLORIDA

BROWN AND CALDWELL
Phoenix, Arizona

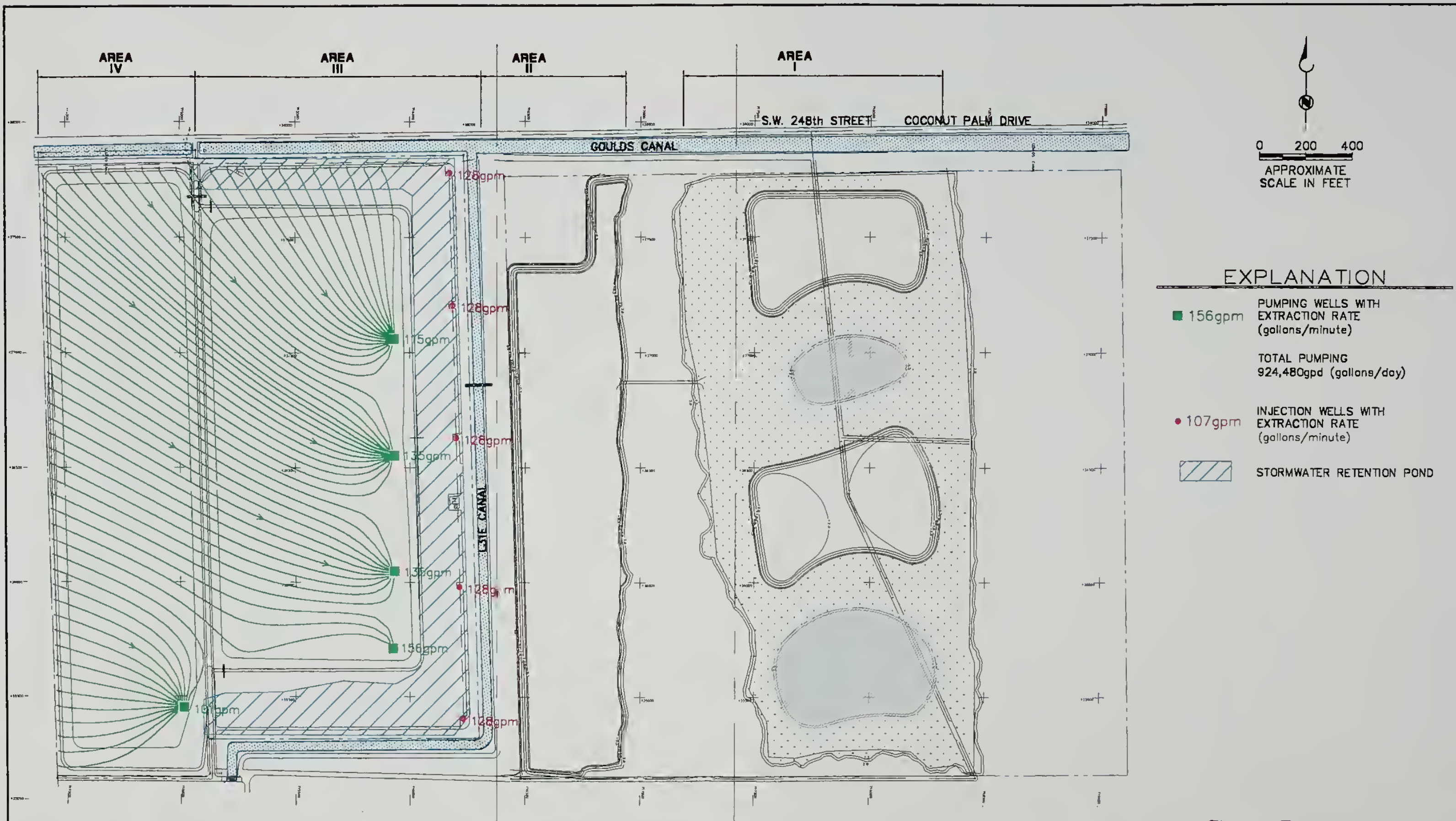


Figure 7

OLD SOUTH DADE LANDFILL
CLOSURE ENHANCEMENT
HYDRAULIC CONTAINMENT
EXTRACTION/INJECTION SYSTEM
DADE COUNTY, FLORIDA

BROWN AND CALDWELL
Phoenix, Arizona



BOUNDARY CONDITIONS

- Constant Head
- River
- Drain
- No Flow
- Horizontal Flow
- Boundary (colors represent different layers)

Figure 8
 OLD SOUTH DADE LANDFILL CLOSURE ENHANCEMENT
 PLAN VIEW OF BOUNDARY CONDITIONS IN THE
 OSDL SHORELINE MODEL
 DADE COUNTY, FLORIDA



Figure 9
 OLD SOUTH DADE LANDFILL CLOSURE ENHANCEMENT
 PARTICLE TRACKING SHOWING FLOWPATHS OF
 TREATED GROUNDWATER AT THE OSDL SITE
 DADE COUNTY, FLORIDA

BROWN AND CALDWELL



Figure 10
 OLD SOUTH DADE LANDFILL CLOSURE ENHANCEMENT
**PROPOSED NEW NEAR-SHORE
 MONITORING WELL LOCATION**
 DADE COUNTY, FLORIDA

